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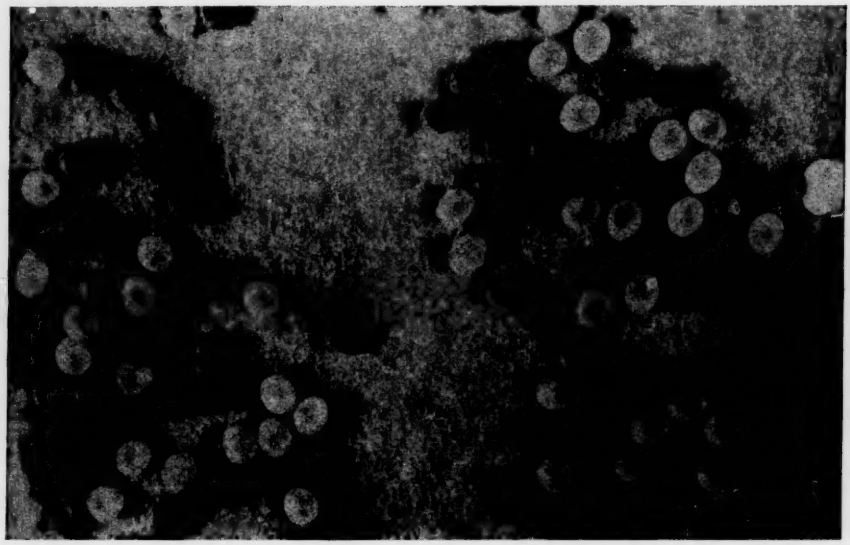

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The American Genetic Association

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YAKS, GALLOWAY COWS AND HYBRIDS

Figure 1

A—The yak bull used to sire all the hybrids produced. *B*—Two of the Galloway cows used in the experiment. *C*—Three hybrid heifers and a yak heifer. The yak heifer is at the left elbow of the herdsman. Note the greater size and blockier conformation of the hybrids

YAKS AND YAK-CATTLE HYBRIDS IN ALASKA

W. T. White, Ralph W. Phillips and E. C. Elting
*United States Department of Agriculture**

THE yak is peculiarly adapted to the uplands of Central Asia, a region characterized by rough terrain, cold climate and scant grazing during many months of the year. Descriptions of the yak, discussions of its ability to live and work under rigorous climatic conditions and descriptions of yak-cattle hybrids in Asia are given elsewhere.[1,2] Since the yak and yak-cattle hybrids are so valuable to Tibetans, Mongolians and other Central Asiatic peoples as sources of power (chiefly for packing), milk, meat, skins and fiber, it seemed that they might be useful in certain areas of Alaska. Therefore, an experiment was undertaken in 1919 by the Alaska Agricultural Experiment Stations to determine the possible usefulness of these animals in that Territory.

Cattle can be maintained, with a limited amount of supplemental feeding, on the ranges of Kodiak and neighboring islands, and the Cook Inlet coastal area, where the climate is relatively mild. But in the interior of Alaska a hardier animal is required, unless shelter and feed are supplied. The hardy reindeer subsists on the open range and tundra principally on a type of lichen (*Cladonia rangiferina*) which grows extensively only in the arctic regions north of the Yukon River, west of the Tanana River and in the lower Kuskokwin River valley. There are, however, extensive ranges on the northern slopes of the Alaska Range where grass and browse types of forage predominate, and where, because of light precipitation and prevailing high winds, large areas lie exposed for browsing throughout the winter. This area is bounded on the north by the Yukon River, on the east by the Alaskan-Canadian boundary, on the south by the Alaska Range, and on the west by the tundra and timbered and mossy areas of the Yukon River flats. Obviously, numerous localities within this region are not suited to grazing, but there are large acreages of suitable ranges on the higher elevations and mountain slopes and passes. The better-drained slopes and tablelands are characterized by bunch grasses and sedges which are especially valuable for winter feeding. Wild peavine, silverberry, and willow browse are available on sandy areas and river bars when they are exposed for grazing. It appeared that the yak and possibly yak-cattle hybrids might be adapted to grazing in this region. Observations on the available range in this area and its carrying capacity indicate that it might support up to approximately 150,000 animals.

The experimental work was conducted from 1919 to 1932. Numbers were limited, data are incomplete and a part of the time the animals were under sheltered conditions. However, the results do indicate the possible usefulness of these animals in the portion of Alaska described above, and they are summarized here because of their scientific interest and their possible usefulness in the development of this and similar regions.

Observations on Yaks

Three consignments of yaks were obtained from the Canadian Government in 1919, 1923 and 1930, including totals of three males and six females. Two of the females failed to breed, one female

*The work summarized in this report was conducted by the Department's Alaska Experiment Stations under the supervision of the Office of Experiment Stations. This work was closed out when these Federal Experiment Stations were discontinued during the fiscal year beginning July 1, 1932.

and her calf and one of the bulls died. Hence a very limited number of foundation animals was available for use in establishing a herd.

The yaks were maintained at the Fairbanks Experiment Station from 1919 to 1930. The elevation is about 420 feet, which is far below the elevation of the native home of the yak. Only limited range areas were available and deep winter snows made winter grazing impossible. Under these conditions, much difficulty was experienced in obtaining satisfactory reproduction. In August, 1930, the animals were moved to a range on a large plateau near Lignite. Here the elevation varied from approximately 1,200 to 2,500 feet. An immediate improvement in the condition of the animals was noted. They improved in flesh, became more active and more tractable, hoofs that had caused trouble because of excessive growth assumed their natural shapes, and coats made a more satisfactory growth and had more luster. Breeding difficulties appeared to diminish but the work was terminated too soon thereafter to be certain of this point. These observations on breeding are similar to some made on yaks in Canada, and reported by Rothwell.[3] A herd was imported and was maintained at a low altitude for about two years. They did not reproduce, and were moved to a higher altitude in the Rocky Mountain Park. Cows started breeding fairly regularly in the succeeding year.

Some observations on the feeding habits of the yak are of interest. When the forage is covered with snow, the snow is trampled, then nuzzled away, particularly from the low bunch grasses. The yak crops grass close to the ground. At Lignite, bunch grasses provided most of the winter forage. Some sedge and peavine were grazed, but other than bunch grasses, most of the remaining fare was browsed from willow and other browse plants. The yak continues to graze during periods of low temperature, even during high winds, and it feeds into the wind, rather than away from it as cattle and horses commonly do. Yaks travel as they feed, and it was not uncommon for the herd to move twenty to thirty miles during a twenty-four hour period. While running at will on the range during the summer, the herd broke up into small groups of two and three, but while scattered over large areas the various groups seemed to maintain contact. During late fall and winter the bulls usually fed by themselves in some sheltered section of the range, and did not move about as much as the cows. Yaks seem to prefer water to snow during the winter, but will not travel any great distance to obtain water if loose or uncaked snow is available.

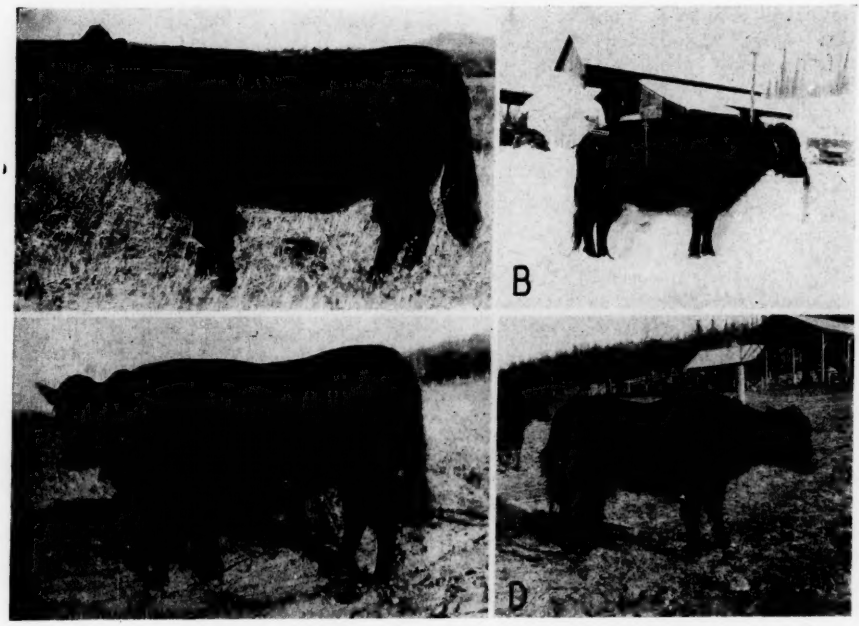
In general, the yaks appeared to be able to sustain themselves satisfactorily on the ranges in this area of Alaska. Low temperatures and lack of water during the winter, and presence of mosquitoes, unless in unusual numbers, during the summer did not appear to inhibit satisfactory maintenance or growth and development.

Observations on Yak-Galloway Cattle Hybrids

Eight hybrid and backcross animals were raised to maturity. These included six females and two males. The cows weighed from 1,030 to 1,360 pounds each, as compared with the yak cows which weighed from 700 to 900 pounds each.

The Galloway was used in the production of these hybrids since this breed was developed in the rather rigorous climate of Scotland, and since it had been used in experiments for crossing with Holstein cattle at the experiment station on Kodiak Island. The Galloway cows in that herd were considered to be fair milkers but were not high for the breed. This breed is essentially of beef conformation. Of 13 cows used in the experiment on Kodiak Island the highest lactations of the various cows ranged from 1,596 pounds in 133 days to 4,451 pounds in 227 days. This indicates the nature of the Galloway stock from which the Galloway cows came that were used in producing the yak-cattle hybrids.

Examples of the stock used and of the



YAK-CATTLE HYBRIDS AND A BACKCROSS

Figure 2

The females in *A*, *B* and *C* are F_1 animals resulting from mating a yak bull to Galloway cows. The female in *D* was sired by a yak bull and was from an F_1 cow, and is thus ¾ yak and ¼ Galloway.

hybrids produced are shown in Figures 1 and 2. Examination of these photographs will reveal that the hybrids are of better beef conformation and greater size than yaks. The hump of the yak is almost lacking in the hybrids, the ribs are covered more thickly with flesh and there is considerably greater development of the loin, rump and round than in the yak.

Milk records were obtained on one hybrid female during 1927-28 and the yield for the lactation was 3,459.5 pounds (10.5 pounds daily), with a butter fat content of 6 percent. A Galloway cow tested during the same years produced 4,999 pounds of milk (10 pounds daily) during her lactation, the butterfat content being 4.7 percent.

Five of the six females (hybrids and backcrosses) were fertile. The nonbreeding hybrid had a normally developed reproductive tract, and infertility apparently was due to a cystic ovary which was revealed on post mortem. The two hybrid males were sterile, and this is in accord with the findings of workers in Russia and observations in China, summarized elsewhere.[2]

Like the yaks, the hybrids were maintained in limited quarters at Fairbanks until the fall of 1930. Observations during the next two years when they were on open range at Lignite indicated that they did not withstand extremely low temperatures with as much comfort as the yaks, but they apparently had sufficient hardiness to withstand satisfactorily the temperatures encountered in that area.

These observations indicate that hybrids combine enough of the resistance of the yak and the beef conformation of the Galloway to be satisfactory for beef production in this region of Alaska. In this work yak bulls were mated to Galloway cows, but the reciprocal cross should also be satisfactory. In Central Asia domestic-cattle bulls are usually mated to yak cows when hybrids are desired.

Observations on Meat

Two animals were slaughtered, one being a ten-year-old yak cow and the other an eight-year-old hybrid cow.

The yak cow weighed about 700 pounds and the carcass weighed slightly over 50 percent of the live weight. A number of persons eating various cuts of the carcass judged it to be "sweet and tender."

The hybrid cow weighed 1,360 pounds, and the dressing percentage was 52. When served as roast or stew it did not appear to be distinguishable from beef, but when served as steak it was lacking in tenderness unless cooked longer than beef.

The meat of these two carcasses appeared to compare favorably with that of beef cows of similar age. There was no opportunity to test the meat of steers of normal market age.

Application

Observations on the great usefulness of the yak in Central Asia and the limited observations recorded above indicate that it might prove to be a very useful animal in the range area of Alaska described in this paper, if future developments in Alaska warrant the establishment of such an industry. Because of the remoteness of the native home of the yak, it has received little attention. Only in recent years have Russian workers undertaken some experimental work with yaks and yak-cattle hybrids. This species is worthy of more attention in other areas of rigorous climate to which it may be well adapted.

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✦

Eighth Genetics Congress to Meet at Stockholm in 1948

The Eighth International Congress of Genetics will be held in Stockholm in the summer of 1948. The date will be announced later, when more is known about other congresses planned for 1948. Swedish geneticists have formed an Organization Committee for the Congress, with Professor Gunnar Dahlberg, of the University of Uppsala, as chairman, and Professor Gert Bonnier, Institutet för Husdjursförädling, Wiad, Eldtomta, as general secretary.

✦

Experimental Cytology Congress Set for July 1947

The Sixth International Congress of Experimental Cytology will meet in Stockholm July 10th-17th. It will be open to scientists of all nationalities except German and Japanese, according to the Swedish organization committee.

A series of symposia are planned on the following main subjects: Chemical constituents of the cell; Submicroscopic structure of the protoplasm, including viruses; Nuclear and cytoplasmic interactions; Cell metabolism; Development, growth and differentiation.

The committee advises that those who wish also to attend the Congress of Physiology at Oxford will be able to arrive there in ample time by leaving Stockholm on July 16th or 17th.

Address all communications to the Secretaries, Professor T. Caspersson and Docent H. Hyden, Karolinska Institutet, Inst. for Cell Research, Stockholm.

VARIABILITY IN THE EXPRESSION OF THE GENE FOR BRACHYDACTYLY IN MAN

C. W. McNutt

Department of Anatomy, University of Wisconsin

THE three persons whose hands and feet are illustrated herewith are members of a family in which a history of brachydactyly is known accurately for four generations. (See Figure 4.) This family displays an unusual concentration of characteristics, such as short middle phalanx of the index and other fingers, absence of middle phalanx, extra segmentation, and short metacarpals, which ordinarily are inherited singly in other families.

The family pedigree has been compiled entirely from information secured from members of the family and the family photograph album. The family traces its ancestry to Holland. The history starts with a man and a woman who were either brother and sister or first cousins. Since the woman married twice, the condition runs through three sublines. With the possible exceptions of III-12, 14, 15, the characteristic is transmitted as an autosomal dominant. It is questioned whether II-8 and 10, the fathers of these apparent exceptions, were truly normal, as reported; of course, they may represent so-called "normal overlaps," but, lacking radiographic proof pro or con, it is equally possible that they had such mild brachydactyly that their hands passed for normal.

Description

In general appearance the hands are short, stocky and thick. There is a shortening of both the fingers and palm. The fingernails are large, thick and well developed. Figure 5 shows the dorsal and volar surfaces of the hand of IV-11 at 23 years of age.

It will be noted in the photographs that the two hands are asymmetrical. The digital formula, expressing the relative length of the fingers, is as follows:

Right — $4 > 5 > 3 > 2 > 1$
Left — $4 > 5 > 3 = 2 > 1$

The knuckle formula is symmetrical in the two hands:

Right — $2 > 3 > 5 > 4 > 1$
Left — $2 > 3 > 5 > 4 > 1$

Both the digital and the knuckle formulae differ from those usually encountered.

A brother of the man just described, aged 18, (IV-14) apparently had symmetrical hands, but following an injury the fourth and fifth fingers of the right hand could not be fully extended. However, the symmetry of his hands differs from the usual pattern in man. His digital formula is:

Right — $3 = 4 > 2 > 5 > 1$
Left — $3 = 4 > 2 > 5 > 1$

Knuckle formula as follows:

Right — $2 > 3 > 4 > 5 > 1$
Left — $2 > 3 > 4 > 5 > 1$

The father, aged 61, (III-18) possessed still another pattern:

Digital formula:

Right — $3 > 2 > 4 > 5 > 1$
Left — $3 > 2 > 4 > 5 > 1$

Knuckle formula:

Right — $2 > 3 > 4 = 5 > 1$
Left — $2 > 3 > 4 = 5 > 1$

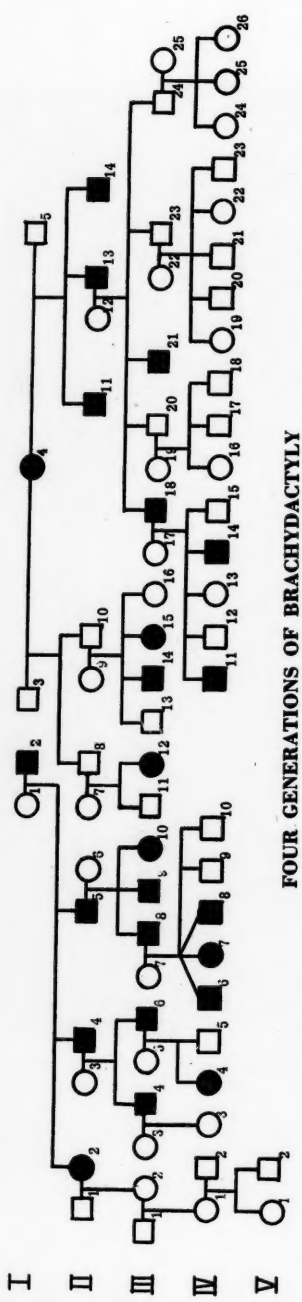
This digital pattern, one which occurs rather frequently in a "normal" population, is brought about by compensations in the phalanges to overcome an atypical metacarpal pattern.

An examination of radiographs of these hands reveals even more interesting variations. Figure 3*C* is a radiograph of the hands of IV-11 (compare with Figure 5). The striking features are a rather marked symmetrical reduction in the middle phalanx of fingers 2, 3, 4, and 5 and

AFFECTED DIGITS OF A FATHER AND TWO OF HIS SONS

Figure 3

A shows the digits of III-18. *B* shows the hands of his son IV-14 at the age of 18 years, and *C* shows the hand of the other affected son IV-11. *D* and *E* show the right feet of individuals IV-11 and IV-14, respectively. While the hands of all individuals shown here are definitely brachydactylous, the form of the fingers and the shape of the hand as a whole are quite different. The variability of this character as expressed in this family seems to be greater than that in most brachydactylous families recorded in the literature.



FOUR GENERATIONS OF BRACHYDACTYLY

Figure 4

In this family the character is generally inherited as dominant. Two brothers with normal hands (II-8 and II-10) transmitted brachydactyly although they themselves did not show it. The failure of the brachydactyly gene to demonstrate its usual penetrance in these two instances remains unexplained.

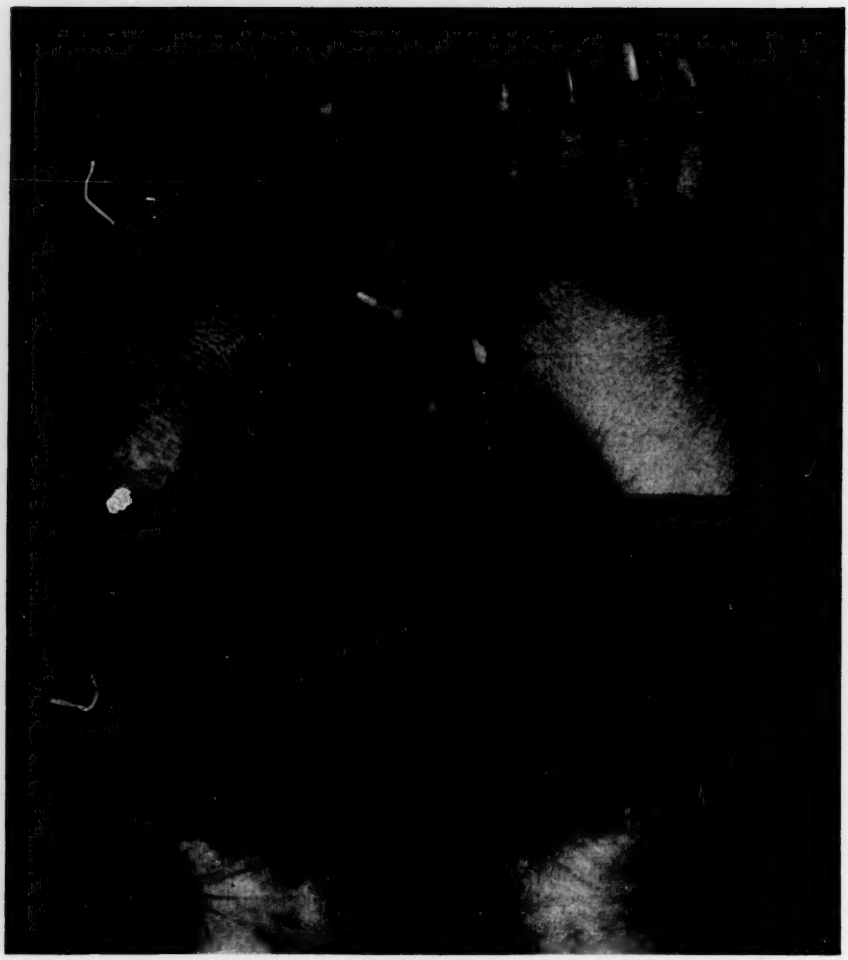
extra segments in fingers 2 and 3 which appear to be due to a segmentation of the basal phalanx, which is asymmetrical in the two hands. The middle and basal phalanges, including the extra segments in the second and third fingers are ankylosed. Since the youngest individual in these cases (IV-14) was 18 years old the epiphesial lines are all fused so that their relationship remains unknown.

The metacarpal bones are also rather extensively affected, the fourth being the most reduced, with the first, fifth and perhaps the third and second following in that order.

No definite deviations can be noted in the carpus. One gets the impression that the carpals are relatively small and somewhat misshapen, causing more than the normal "flare" to the metacarpals. Also there seems to be a fusion of the fifth metacarpal with the hamate. The radius and ulna appear to be rather widely articulated at the wrist.

On the hands of IV-14 (Figure 3*B*), the same general regions are affected. However, the pattern is different in that the middle phalanx is entirely absent in the index finger of the left hand, and in the index and little fingers of the right hand. The reductions in the metacarpals follow a different pattern but the fourth, fifth and first are also the most severely affected. Both these hands also exhibit the accentuated flare of the metacarpals and an apparent fusion of the fifth metacarpal and the hamate. The styloid process of the ulna is absent but the articulation of the radius and ulna at the wrist appears to be more nearly typical than in the former case.

The radiographs in Figure 3*A* are of the father's hands (III-18). Again the pattern is different, but the same general changes are obvious. The joints between the three phalanges of the third and fourth fingers of both hands seem to be functional. The middle phalanx is reduced in the second, third and fourth fingers and absent in the fifth finger of both hands. There is some evidence of an extra segmentation and subsequent ankylosis of the basal



THE "FINGER INDEX" ILLUSTRATED

Figure 5

The hands of individual IV-11 whose fingers are shown in X-ray in Figure 3*C*. Note that the fourth finger is the longest and that the fifth finger comes next in length in contrast to the normal hand where the third finger is longest with the fourth or the second the next. In this family there is considerable variation in which of the fingers is longest.

phalanx of the fourth fingers in both hands, and of the third finger of the right hand. The same three metacarpals are affected symmetrically in both hands but with a slightly different pattern from that in the two preceding cases. The carpus has the same appearance as in the preceding two cases and there is no styloid process on the ulna.

Brachydactylous Feet

In only two individuals was it reported that the feet were also affected (III-4 and III-6). However, on inquiry it was learned that members of the family who had brachydactylous hands had small feet and characteristically high insteps. The largest shoe worn by these individuals was 6½, and some difficulty was reported in finding shoes that fitted comfortably. Radiographs were made of the right feet of the two sons whose hands have been pictured (Figure 3*D, E*). It will be noted that the middle phalanx of the 2nd, 3rd, 4th, and 5th digit is entirely absent and in some instances there is fusion of the remaining two phalanges in the digits. There is an apparent general uniform shortening of the metatarsals which also contributes to the shortening of the feet.

More Than One Gene for Brachydactyly?

Even before Mendel conducted his experiments, individual cases of brachydactyly, and in some instances family pedigrees, were noted and published. After the rediscovery of his laws, brachydactyly was the first human characteristic to be shown to follow the Mendelian manner of inheritance. Various published pedigrees showed that one particular pattern of bone structure sometimes occurred with striking uniformity throughout a given family. This seemed to indicate that differences in pattern are controlled by different genes. However, as new family histories of this condition were published, confusion arose, which persists to this day, as to the exact nature of the inheritance of this character. Usually brachydactyly appears to be transmitted as a dominant, sometimes as an irregular dominant, and in some limited pedigrees a recessive inheritance is indicated.

Mohr and Wriedt reported a new type of brachyphalangy restricted to the middle phalanx of the index fingers.[9] They made an excellent analysis of the conditions and reviewed the literature on the subject distinguishing nine distinct types of brachyphalangy (usually middle phalanx shortened), including hypophalangy (absence of phalanx, usually middle one) and hyperphalangy (extra segmentation of phalanx, usually the basal one).

Shortening of the metacarpals and metatarsals has been observed even more frequently than shortening of the phalanges, but family histories have not been published as frequently. Stiles and Steggerda have made recent reports[10,11] on the inheritance of this condition in two families, and cite other work. They report that it is inherited as a dominant autosomal character with varying degrees of expression and pattern.

In the family reported in the present paper not only are several characteristics combined which in other families are inherited singly, but in addition the carpal and tarsal bones are apparently affected, as are the radius and ulna. Cohn and Ravin have reported[4] valgus deformities occurring in association with brachydactyly. An abnormality of the spine was reported by Boorstein[3] in a case of brachydactyly. Not infrequently a case of malformation of the breast muscles associated with brachydactyly is reported. Fürst in 1900 reviewed 12 such cases.[6] The latter associations with brachydactyly have not, as yet, been shown to be inherited, and the possibility remains that the phenotypical resemblance to inherited brachydactyly in the latter cases has no genetic basis.

Brachydactyly is inherited as a recessive in the chicken,[5] the mouse[1] and the rabbit.[7] It is similar to human brachydactyly in that the expression is chiefly in the extremities with varying degrees of expression and pattern, with some normal overlaps. This unusual expres-

sion of the gene for brachydactyly, both in the wide range of abnormalities produced, its asymmetry, varying patterns and normal overlaps was extremely confusing until it was shown that the development of myelencephalic blebs in the young embryo of mice homozygous for brachydactyly initiates a chain of developmental changes culminating in abnormalities in the extremities and other organs of such homozygotes.[2] In brachydactylous rabbits the breaking down of the small blood vessels in the feet of the embryo produce secondary changes resulting in brachydactyly.[8]

Brachydactyly in man, being a dominant character, is certainly the result of another factor, but it is suggested that the many distinct patterns of human brachydactyly may actually be the result of the same gene. The changes produced by this gene are in all probability much more profound than is commonly supposed, producing in the heterozygous condition chiefly changes in the extremities but in some individuals changes in the long bones of the arms and legs, and, as mentioned, the spine may be involved. Mohr and Wriedt mention authors who believe that in some families there is a general shortening of the stature indicating that the skeleton as a whole may be affected.[9] Also, as has been suggested, associated changes in the musculature may be involved. Thus the action of this gene in the heterozygous state affects the body generally, and, as Mohr and Wriedt point out in the family reported by them, the condition in the homozygous state probably results in much more pronounced effects which likely are lethal.

The appearance of human brachydactyly, its mode of inheritance, and the knowledge we have of brachydactylous laboratory animals makes it appear that the condition as seen postnatally is a secondary effect of some other embryonic abnormality, which probably occurs during or before the fifth week of embryonic life. The primary cause is such as to allow for the normal overlaps in some individuals and for a varying expression of the character as observed in the adult.

The striking uniformity in the expression of brachydactyly, with variants around one pattern, in some families may be accounted for on the basis of different genetic backgrounds upon which the gene for brachydactyly must express itself. The varying expressivity and reduced penetrance exhibited by this dominant gene is thus postulated to be a reflection of the fact that brachydactyly is really a secondary result of some early developmental phenomenon, as yet unknown and that the genetic milieu affects the expression of the character.

Summary

1. A new case of human brachydactyly is described which combines several conditions inherited separately in other families.
2. Similarities and differences exhibited in human brachydactyly and that of laboratory animals are discussed.
3. It is suggested that many if not all forms of human brachydactyly are the result of the same dominant autosomal gene with reduced penetrance and varying expressivity.

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THE AGE FACTOR IN WEIGHT OF YELLOW MICE

Weight Reduction of Ageing Yellows and "Thin-Yellows" Revealed in Littermate Comparisons*

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COMPARISON of the weights of yellow and non-yellow mice has shown definitely that the obesity of the yellow mice is associated with the yellow gene A^y. This gene, first described by Cuenot in 1905, and worked out by Durham, Little and others has been found to have a lethal effect in the homozygous state. Kirham, McDowell[4] and Robertson[5] have found that the lethal effect of the gene occurs by the eighth day of embryonic life. The gene A^y is an allele in the agouti series, on the fifth chromosome. The remainder of the agouti series consists of white bellied agouti (A^w), agouti (A), black and tan (a^t), and non-agouti (a). Since the homozygous condition has proven lethal, the yellow mice in this laboratory have been inbred with black non-agouti mice and mating *inter se* have given an inbred stock.

The obesity of the yellow mice is, in all probability, part of the action of the A^y gene itself and not of an independent gene, otherwise there would be thin yellow mice and fat non-yellow mice occurring in the litters. Various experiments have shown that the yellow gene, when introduced on other backgrounds such as albinism, increased the amount of obesity.[2] There has not been much recent work published on the problem of yellow and non-yellow weights. Continued observation in this laboratory has shown that there are tendencies toward variations not heretofore mentioned. The most recent work done on the problem of yellow obesity has been on the utilization of food, and it was concluded that the obesity was the result of increased appetite and reduced energy requirements, that is, more efficient utilization of the food.[3]

Materials and Methods

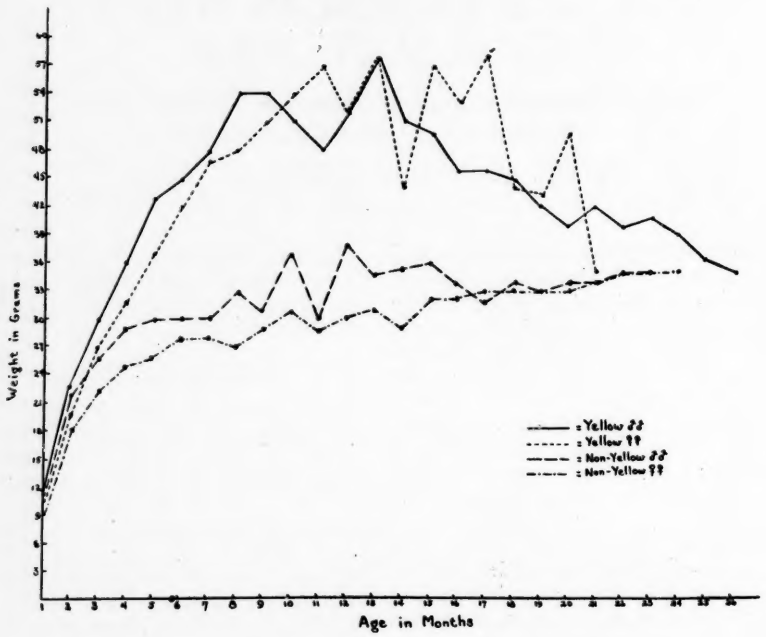
The hybrid yellow and non-yellow mice used in the present study were obtained by mating JAX yellow females (A^y *a BBCC*) with JAX strain *ce* males ($AABBc^ec^e$). Each stock has been inbred over thirty generations. The extreme dilution mice were large, averaging 28-32 gms. in weight, but were not obese like the yellow mice, particularly with reference to the internal fat. In the inbred yellow stock, where obesity has diminished with extended inbreeding, the yellow animals averaged 27-30 gms. in weight.

The F_1 generation males and females from this cross were saved as virgin animals and weighed at approximately monthly intervals throughout life. The total number of animals used was 161, divided as follows: 33 yellow females, 39 yellow males, 47 non-yellow females, and 42 non-yellow males.

Results

By comparison of average monthly weights (Figure 6), it was noticed that the yellow females were the heaviest in the group, followed by yellow males, non-yellow males and non-yellow females. The yellow animals, both male and female, were at the peak of their weight between seven and eighteen months of age. It was evident that old

*This work has been aided by grants to the Roscoe B. Jackson Memorial Laboratory from the Commonwealth Fund, Anna Fuller Fund, Jane Coffin Childs Memorial Fund for Medical Research, and the National Advisory Cancer Council.



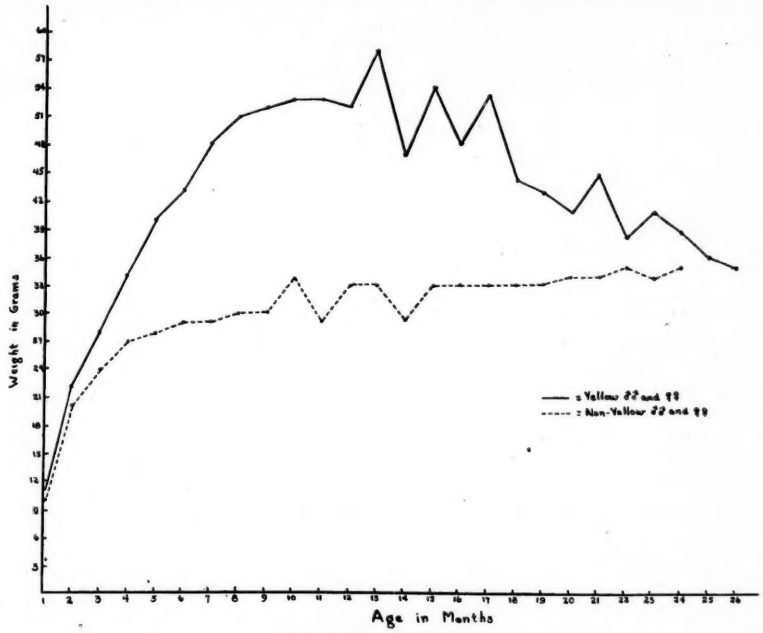
YELLOW AND NON-YELLOW GROWTH CURVES

Figure 6

Monthly weight comparisons of yellow and non-yellow hybrid mice derived from the cross yellow female × *ce* male. Note that the non-yellow mice continue, in general, to gain weight slightly after they have reached maturity. The yellow mice reach a maximum weight after which they decline in weight until in extreme old age they weigh but little more than non-yellow controls.

age brought on a decrease in weight of the yellow mice so that by the time they reached two years of age they were not significantly heavier than their non-yellow littermates. Danforth[2] reported that the yellow females became heavier than the males but not that there was a mid-life peak in their weight or that they decreased in weight with old age more rapidly than non-yellow littermates.

As weights were recorded it became very noticeable that there were some thin yellows. Danforth[2] has said that all thin yellows were unhealthy, but such was not the case with these mice. They were in exceptionally good health and appeared to be about the same weight as their non-yellow sibs. Careful charting of individual weights has shown that some never do become obese. This is shown graphically by comparison of these thin yellows with fat yellows and non-yellows (Figure 8). Other workers at the Jackson Laboratory have noted this phenomenon and in discussing it, it was thought that there might be modifiers at work so that on different backgrounds, this weight difference might be more pronounced, or there might be a very closely linked gene. However, a genetic explanation is not easy since obese F_1 yellows and thin F_1 yellows have been recorded from the same yellow female and *ce* male. Even though



POOLED AVERAGES

Figure 7

When the weight averages shown in Figure 6 are combined for both sexes, some of the variations are smoothed out to show the trends more clearly.

this is so, the thin yellows had the same common ancestry in the yellow stock.

Other facts have been observed about the yellows in comparison with the non-yellows. First, Castle showed in detail that the gene A^y increased body length in both types.[1] Then Benedict and Lee noted that the reproductive cycle was much shortened in the yellows and thought that it was due to an endocrine unbalance. The yellows did not live as long nor were they as vigorous as their non-yellow sibs; this might have been due to the obeseness itself or to metabolic disorders that might have arisen from endocrine dysfunction.[4] It was interesting to observe that a female sib of thin yellows 2245 and 2246, castrated at three days of age and maintained to an advanced age, became as obese as many intact yellow females.

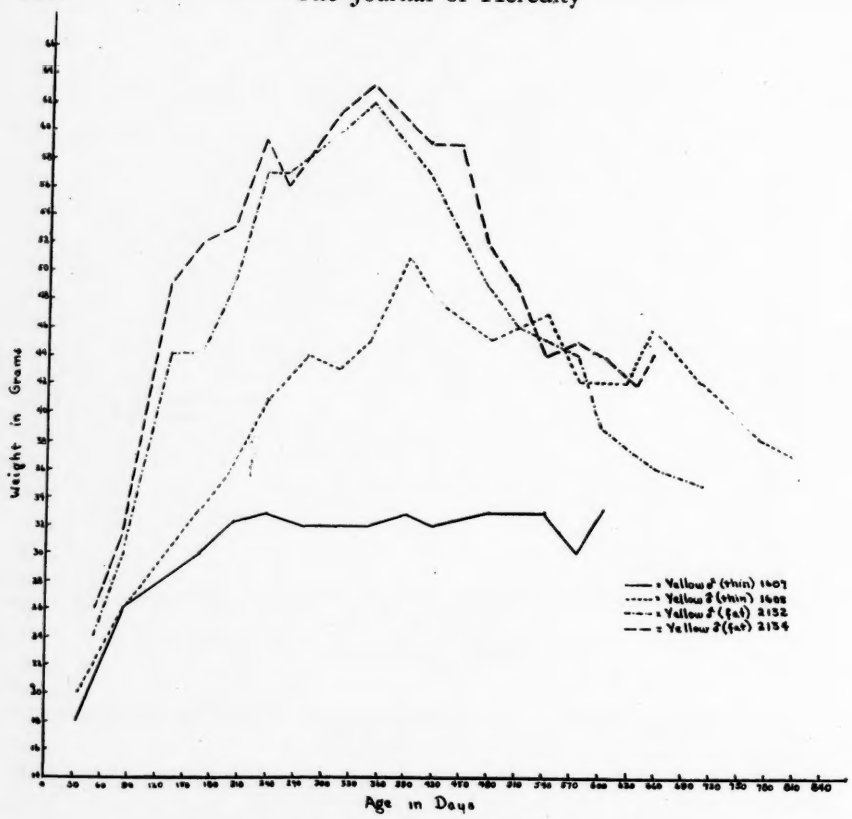
Figures for the monthly averages* of the animals were very interesting and although they did not show the extremes, they aided in interpreting the graphs (Figures 6 and 7). The highest weight recorded for a yellow animal was 73 grams, for a yellow female 350 days old. This animal was exceptionally heavy; other mice usually were between 60 and 68 grams.

Summary

Weights were recorded on 161 mice of the F_1 generation of a strain JAX yellow females $\times$ strain JAX *ce* males cross. They were divided as follows: 33 yellow females, 39 yellow males, 47 non-yellow females, and 42 non-yellow males.

These weights when tabulated at

*Tables containing this information are filed as Document No. 2329 and may be obtained by writing directly to the American Documentation Institute, 1719 N St., Washington 6, D. C.



WEIGHT CURVES OF "THIN" AND "FAT" YELLOWS
Figure 8

Individual weight curves of four yellow mice, two of them "fat" and two of them "thin." An occasional yellow which does not fatten as most yellows do has been noted in these cultures. Their growth-curves resemble that of normals rather than that of yellows. Apparently they are healthy and at present no explanation is known for their unusual growth-pattern.

monthly intervals, showed that yellow females were the heaviest of the four groups followed by yellow males, non-yellow males and non-yellow females.

Peak weights were recorded between 7 and 18 months of age and after 18 months of age the yellows, both male and female, decreased in weight so that by 24 months of age they were approximately the same weight as non-yellow littermates.

Some thin yellow mice were found and the genetic problem created by their occurrence was discussed.

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A STUDY OF THE FIRST FIFTY YEARS OF TENNESSEE WALKING HORSE BREEDING

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IN recent years there has been a decided increase in light horses of all types, reflected in growing annual registrations of Thoroughbreds, Standardbreds, and Morgans. At the same time several new breeds have become sufficiently numerous and important so that registry associations have been established. These include the American Quarter Horse, the Palomino, and the Tennessee Walking Horse. Of these three organizations the Tennessee Walking Horse Breeders Association has shown the largest gain in annual registrations. Since it was organized in 1935 it has registered a total of 15,698 animals by 1945. (Table I.) Certain conditions in connection with the origin of this breed suggested that a comparison with Steele's[5] analysis of the three standard light horse breeds would be of interest.

Origin of the Walking Horse

The breed gets its name from its "free and easy" gait, which was early found to be especially conducive to the comfort of the rider during the long hours spent in covering the wide reaches of the larger plantations. For this reason it at one time bore the name, "Plantation Walking Horse."[4] This smooth and gentle saddle-motion is characteristic of the three natural gaits of the breed, "flat-foot walk," "running walk," and canter. It was for the practical purpose of fixing this attribute that the Tennessee Walking Horse has been developed as a pure breed.

TABLE I. Annual Registrations of Tennessee Walking Horses, 1935-44.

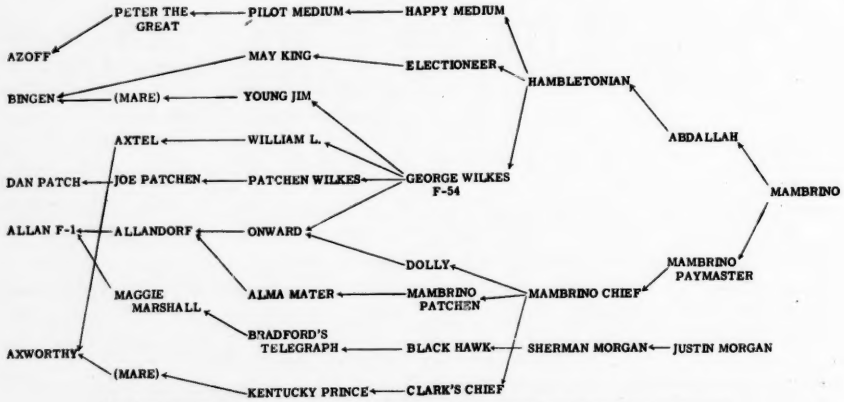
Year	Number Registered	Per cent increase over previous year
1935	208	
1936	240	15.3
1937	534	89 1
1938	566	5.9
1939	1,382	144.1
1940	1,506	8.9
1941	2,150	42.7
1942	2,518	17.1
1943	2,609	3.6
1944	4,005	53.5
Total	15,698	

The Tennessee Walking Horse was not the result of a planned, unified program of breeding, but has been in process of development for at least a century. Its cradle was the southern bluegrass section of Tennessee, an area which had experienced a rise and later a sharp decline in popularity of the Thoroughbred. In spite of this adverse experience with the Thoroughbred, we need not be surprised that this breed was important in the development of the Walking Horse. In addition, in more recent years, crosses with two other breeds, the Standardbred and the American Saddle Horse have been frequently made.

For the purpose of this study the origin of the Walking Horse was considered as dating from 1886, the year in which the Standardbred stallion Allan F-1 (ATR7623) was foaled. This event was crucial in breed history because Allan F-1 is commonly considered to be the foundation sire of the breed.

Allan F-1 has an interesting pedigree (Figure 9). He was a Standardbred entered in the American Trotting Horse Register, which at that time was not a closed stud book. This accounts for the paradoxical fact that among his collateral relatives are found several outstanding animals belonging to other breeds. Among these are included Axworthy, Azoff, Dan Patch, and Bingen.

It will be seen that on his sire's side Allan traces directly to Hambletonian 10, the foundation sire of the American Trotter. Through Hambletonian, the sire line runs to Mambrino, one of the great foundation animals of the American Saddle Horse; Allan also traces to Mambrino through two other lines.



PEDIGREE OF ALLAN F-1 SHOWS HETEROGENEOUS ORIGIN
Figure 9

Allan F-1 is considered the progenitor of the Tennessee Walking Horse Breed. Among his ancestors and collateral relatives are found many prominent individuals in the history of other breeds. Hambletonian is the founder of the Trotting Horse and Justin Morgan is founder of the Morgan breed. Axworthy, Dan Patch, Bingen, and Azoff are famous names in other breeds.

Through his dam he traces directly to Justin Morgan, the founder of the Morgan breed. It is evident that this foundation sire of the Tennessee Walking Horse was "bred in the purple."

Methods of Study

The methods used in this study were essentially those developed by Wright[6] and used by him in studying the origins of British Shorthorn cattle. Later Calder[1] applied them to an analysis of Clydesdale breeding in Scotland, Steele,[5] to three breeds in the United States, Fletcher[3] to the breeding of the American Quarter Horse.

In the present study the interaction of five variables was traced in the development of the Walking Horse between 1886 and 1940.

1. The average inbreeding.
2. The average *inter se* relationship.
3. The relationship of the breed to certain selected individuals.
4. The relationship of the breed to the Standardbred and the American Saddle Horse.
5. The generation interval.

For the purpose of this analysis samples were selected from the first two volumes of the *Walking Horse Register*. The number of animals in the samples varied, ranging from 73 to 99. The manner of selection did not give samples completely comparable for tracing trends in breeding. The first group comprised those sires and dams—73 in number—entered in the first two volumes of the registry as the founders of the breed. The second and third groups included all the animals foaled in the years 1924-25 and 1930 respectively. The second group included the foals of two years to provide a large enough number to afford a comparable sample. The fourth group consisted of one-fourth of the foals registered in 1935. These were selected at random, taking every fourth animal recorded as having been foaled in 1935. The last group was composed of the 97 entries in the registry of foals born in 1940. In the following discussion the first sample will be designated as "Foundation animals" and the other samples will be identified by year of birth.

Five-generation pedigrees were compiled for all the animals in the five samples. The pedigrees were seldom complete to the fifth generation, due to the inclusion of animals of unknown breeding in many pedigrees. Many pedigrees traced to registered Standardbreds or American Saddle Horses. Only the ancestry of an animal as given in the Walking Horse Registry was used; no attempt was made to secure it from these other Registries.

Inbreeding and Inter se Relationship

The average inbreeding and *inter se* relationship coefficients for the five samples are shown in Table II.

The coefficients of inbreeding were relatively low in all the groups. It is doubtful whether the trend toward more intensive breeding in the later samples has any great significance. Very possibly much of the increase is due to the more complete information regarding the ancestry of the more recent entries. Hence the inbreeding of 3.62 per cent for the 1940 group may be fairly representative of the breed as a whole. This figure is slightly higher than the average inbreeding of 2.8 per cent reported by Steele[5] for a selected group of 42 stake winning American Saddle Horses in 1940. In similarly selected small samples of Thoroughbreds and Standardbreds Steele reported materially lower inbreeding coefficients of 1.4 and 1.6 per cent respectively.

The Walking Horse appears on the basis of these data to be slightly more inbred than comparable samples from other breeds of light horses. But the inbreeding has not been as great as one would expect on the very widespread assumption that Walking Horses have been developed by extremely close breeding. This impression has probably been strengthened by isolated cases of more intensive line breeding or inbreeding which have occurred. The pedigrees of animals having materially higher inbreeding coefficients are shown in Figures 10 and 11. Even the outstanding exceptions to the average Walking Horse pedigree do not show very high inbreeding coefficients.

The *inter se* relationship shown in Table II is perhaps more important in an analysis of the breed than the inbreeding. It is interesting that the relationship of the foundation animals was 2.96 per cent, a figure slightly larger than 2.8 per cent reported by Steele[5] for stake winning saddle horses of 1940. This means that the Walking Horse, like the other horse breeds studied, has sprung from a relatively heterogeneous foundation as compared with the cattle breeds where *inter se* coefficients of relationship of 8 per cent are reported. Judged by the 5.8 per cent relationship of the 1940 sample it appears that the Walking Horse breed is a somewhat more closely knit unit than are other breeds of light horses.

TABLE II. Inbreeding and Inter se Relationship Coefficients.

Group	Number of Animals	Inbreeding Per Cent	Relationship Per Cent
Foundation	73	1.24	2.96
1924-25	73	1.39	3.12
1930	99	2.49	6.30
1935	86	3.14	6.45
1940	97	3.62	5.80

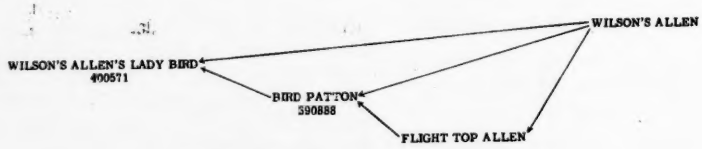
Influence of Specific Animals

In the history of all breeds of livestock it has been found that certain individuals assume outstanding importance. In some cases the prominence of an individual is waning while in others the influence is maintained at a remarkably high level for a number of generations. Five animals were selected for study in this connection, based on their assumed prominence as foundation animals and the frequency with which they appeared in the pedigrees studies. Their relative importance was measured in terms of their direct relationship (percentage of blood) to the four samples. (See Table III.)

When the relationship exhibited over the entire period is considered, Allan F-1 and Roan Allen F-38 emerge as the two most prominent individuals. It will be noted that while Allan F-1 has maintained a fairly constant relationship over the period studied, there has been a tendency to shift away from Hunter's Allen F-10 to Roan Allen in the breeding program. Both of these stallions were sons of Allan F-1. As indicated by the 6.35 per cent relationship of the 1940 sample to Wilson's Allen it is probable that he will assume greater prominence in the next few generations. Wilson's Allen

TABLE III. Direct Relationship, in Per Cent, of Walking Horse Samples to Selected Animals.

Animal	Group			
	924-25	1930	1935	1940
Allan F-1	13.09	16.02	16.35	16.48
Hunter's Allen F-10	8.22	7.32	12.63	7.53
Roan Allen F-38	10.36	20.77	18.89	19.44
Merry Legs F-4	2.05	3.03	5.74	4.63
Wilson's Allen 350075	1.37	2.52	2.90	6.35



LINEBREEDING TO WILSON'S ALLEN
Figure 10

Wilson's Allen is father, grandfather, and great-grandfather of Wilson's Allen's Ladybird. The coefficient of inbreeding for Wilson's Allen's Ladybird to this ancestor is 37.5%. This is equivalent to between one and two generations of brother-sister mating.

was a double grandson of Allan F-1 and sired by Roan Allen F-38. Through his prominent descendants Allan's prominence in the breed will be maintained at a high level in the future.

The importance of these animals can be expressed in another manner. The 16.46 per cent relationship of the 1940 sample to Allan F-1 means that he is more closely related to the sample as a whole than would have been the case had he been great grandsire to each animal in that sample. A relationship of 12.5 per cent would be equivalent to being great grandsire to the group. Thus it is seen that Roan Allen F-38 approaches the position of grandsire to the 1940 sample, a relationship which would involve a coefficient of relationship of 25 per cent.

Influence of Other Breeds

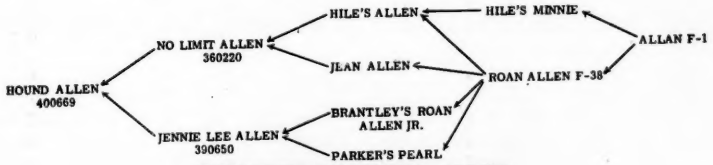
As was stated earlier, the Tennessee Walking Horse was bred primarily from a foundation of Standardbred, American Saddle Horse, and native stock. In fact seven of the 73 foundation sires and dams included in this study were registered Saddle Horses and four were registered Standardbreds. In addition there were five in the group having either as sire or dam a registered American Saddle Horse and six having either sire or dam a registered Standardbred. This in itself would have made each of the breeds of considerable importance in the later breeding of the Tennessee Walking Horse. Since the Walking Horse Association has maintained on open stud book it has continued to be possible to add additional blood from these two breeds. Actually many registered Walking Horses have also been registered with the other associations, or are eligible for registry with them.

In order to measure the influence of the Standardbred and the American Saddle on the Walking Horse, the relationship of each sample to registered animals of these other breeds was determined. The coefficients tabulated in Table IV are very conservative. In some cases animals listed in pedigrees were not definitely identified as being Standardbreds or American Saddle Horses. In these cases the animals were not included even though there was little doubt that the statement of breed registration had merely been neglected.

The figures in Table IV show clearly how much these two breeds have contributed to the Walking Horse. If we consider the two combined it may be said that one-fourth of the breeding is from these sources. Of even greater interest is the decline in the relationship to the American Saddle Horse with an accompanying increase in relationship to the Standardbred. By referring to Table III it will be noted that relationship of the 1940 group to Allan F-1, 16.48

TABLE IV. Direct Relationship, in Per Cent, of Five Groups of Walking Horses to the American Saddle Horse and Standardbred.

Group	Number of Animals	Number Related to American Saddle	Number Related to Standardbred	Relationship to American Saddle	Relationship to Standardbred
Foundation	73	31	29	22.85	16.69
1925-25	73	41	45	14.21	15.92
1930	99	46	81	8.01	19.19
1935	86	42	76	12.79	17.15
1940	97	51	92	9.92	17.22



PEDIGREE OF HOUND ALLEN
Figure 11

In recent samples of the breed, Allan F-1 figures so frequently in the pedigree that he is practically great-grandsire to the Tennessee Walking Horse breed. This pedigree shows the extent of inbreeding to Allan F-1 and to his prominent sons, among whom the most important is Roan Allen. The coefficient of inbreeding of Hound Allen is 14.05 per cent (12.5 per cent from Roan Allen and 1.56 per cent from Allan F-1).

per cent, was only slightly less than the 17.22 relationship to all Standardbred ancestors. Thus it is logical to think that the shift in breeding to the Standardbred has been incidental to a program of breeding directed to Allan F-1.

Interval Between Generations

The information as to the interval in years between generations was very limited. Only in the case of recent animals was any information available as to foaling date of the parents. This the author has included primarily as a result of a suggestion by Carter[2] that the generation interval is shortened in a period of rapid expansion or during the formation of a breed. The average interval between the foaling dates of animals born in 1935 and 1940 and the foaling dates of their sires and dams are found in Table V.

The average interval for both groups of 10.02 years is approximately the same as reported by Fletcher[3] for the Quarter Horse, and slightly less than reported by Steele[5] for the Thoroughbred and Standardbred, but the significance of these differences is doubtful. This was substantiated by the fact that the average interval from sire to offspring foaled in 1930 was found to be 17.3 years. This figure was based on 80 generation-intervals.

TABLE V. Interval in Years Between Generations in the Tennessee Walking Horse.

	Group		
Type of Interval	1935	1940	1935-1940
Sire to offspring	10.56	9.80	10.18
Dam to offspring	10.26	9.48	9.87
Average	10.41	9.64	10.02

Summary

The breeding of the Tennessee Walking Horse was studied by the use of five samples derived from the breed stud books. The information secured is summarized as follows:

1. The average inbreeding for the groups ranged from 1.24 per cent for the Foundation animals to 3.62 per cent for those born in 1940.

2. The average *inter se* relationships ranged from 2.96 per cent for the Foundation animals to 6.45 per cent for those born in 1935. The *inter se* relationship of the 1940 group was 5.8 per cent.

3. The two most outstanding individuals of the breed were Allan F-1, and Roan Allen F-38. Their relationships to the 1940 group were 16.48 per cent and 19.44 per cent respectively.

4. The influence of the Standardbred and American Saddle Horse was shown by the relationship of the groups to each breed. The 1940 group had increased in relationship to the Standardbred and declined in relationship to the American Saddle Horse.

5. The average interval between generations was 10.02 years.

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BRASS TACKS ON THE HIGHWAY OF PROGRESS

THE starting point of this book* is the perplexity of a man of good will in a chaotic world. The signs of confusion and fear are all around him, in the daily news, in the faces of his neighbors, within himself. Mr. Bromfield, with all the earnestness of good intentions and with evident good will toward his fellowmen, sets out to hack his way "out of the jungle and morass of man's troubled life in this Age of Irritation," using his "intellectual processes" as his machete. But, alas, the jungle is too thick, and the weapon he has chosen too dull. He gets lost in the jungle himself.

Mr. Bromfield's method, as the title implies, is to get down to fundamentals. He finds that the intricate fabric of our vast and complex civilization is snagged on four brass tacks. These are:

1. Money is a meretricious abstraction; real wealth is natural resources.
2. In a machine-obsessed age, people forget that agriculture is still the fundamental element in the economy.
3. The misguided and erroneous doctrines of Karl Marx seem to be gaining ground at the expense of the ideals of Thomas Jefferson.
4. Planners and reformers forget man's spiritual side, that he does not live by bread alone.

This meager vision is spread over 303 pages. It is hard to imagine that so narrow a compass could possibly be too wide for a comprehensive discussion of the world's woes. Nor is it. The truth is that Mr. Bromfield does not have much to say. His analysis (which he covers quite thoroughly in a 15 page preface) is perhaps material for a succinct pamphlet. But Mr. Bromfield, who is no doubt a good farmer, is also an adroit wordsman. He knows how to till his acre of talent and reap a book, where a less prolific journeyman might only produce a long letter to a friend.

This book is best when the author is talking about agriculture. In the chapter "Agriculture in Relation to Our National Economy" he makes a detailed and eloquent plea for conservation of our natural resources, particularly agriculture, soil, and forests. The point is well made, and it can not be made too often, that our agriculture can not afford to continue to be prodigal, unscientific and inefficient. The author takes pains to point out that to cultivate a field with an eye only to this year's market price, and with reckless disregard of its fertility and yield next year (to say nothing of next generation) is to court disaster. Disaster is not too strong a word, because the soil is "the largest single segment of our real wealth." Moreover, "unlike deposits of ores or even reservoirs of oil, soil, like forests, is capable of preservation and even renewal and eternal rebirth in its productivity of real wealth." This unique and needful capacity for self-renewal is irrevocably lost when the wasteful practices of "a greedy and inefficient agriculture" permit precious top-soil to be mined to exhaustion or to be washed down to the sea. "What we need is an agriculture of less acreage and greater and more efficient production . . . [like] . . . Denmark, Holland, Belgium and most of France where each acre produces the potential maximum without loss of fertility."

He gives considerable space in this section to the role of the Government in solving agricultural problems. Here he finds himself in a dilemma. He abhors subsidies. They are another example of artificial "money-manipulating." A crop that doesn't pay should be made to pay by the application of scientific methods, not subsidized so that inefficiency is encouraged and perpetuated. But he is too canny a farmer to advocate the slaughter of a fresh cow. So he makes a distinction in the disbursement of government funds between "spending" which he frowns on and "investment" which he favors. This may well be a significant

*LOUIS BROMFIELD: *A Few Brass Tacks.* Harper and Brothers. 303 pp. 1946.

distinction, with which to guide future policy, but to apply it in carping judgment of the Government's desperate measures in the early New Deal is to forget, in the satiety of today's plenty, the calamitous hunger, panic and poverty of those parlous days.

In another place he concludes "that the bases of man's wretchedness and bewilderment are far more of economic than of political or social or racial or national origins . . . and that, if the economic ills . . . could be adjusted, many of these evils would presently disappear . . ." The achievement of this "adjustment" comes not "by short-cuts and fanciful and visionary theories, but by work and experience and faith and wisdom." He calls this an "irrefutable fact." It seems more like an ardent hope. At any rate, as a pattern for salvation it is somewhat nebulous. (It is an interesting reflection on the semantic confusions of our times and of our author that words like "fanciful" and "visionary," which connote imagination and imaginative foresight, are employed here as derogatory terms.) The formulas for solving our economic ills, offered by Left and Right, fail, says Mr. Bromfield, because the "nature of man" is "almost wholly overlooked." This human nature consists of such things as "the weaknesses and vagaries of man, his faith, his almost crowlike urge to collect and to own something . . ." and also "a desire to work and create . . ." Although these qualities are attributed to all men, try as he will Mr. Bromfield has tremendous difficulty in finding spirituality and creativeness in the industrial population. There is something about machine-made things and the men who produce them that seems to him somehow sterile. Perhaps it is their remoteness, even isolation, from the good mother earth whence come all beneficent things. He is of course too sensible to urge that we beat our machines into ploughshares and return to a rural economy. But there does creep in, willy nilly, a set of values whereby the more miles there are between a man and the city (with its *"canaille"* and "the movie house, the bowling alley, the pool parlor and the beer parlor . . .") the happier and more prosperous he will be. It seems silly to have to point out that even if it were every man's desire to own a large and fertile farm, in Ohio, say, there would not be enough land to go around. It is perhaps unfortunate, but industrialism and large cities are here to stay, and the evils that machines engender and that over-crowding populations spawn will not be cured by a Malabarcentric view of the universe.

When Mr. Bromfield steps off the farm, into the great world of international affairs, he is entirely out of his element. Good will and earnestness alone are simply not enough.

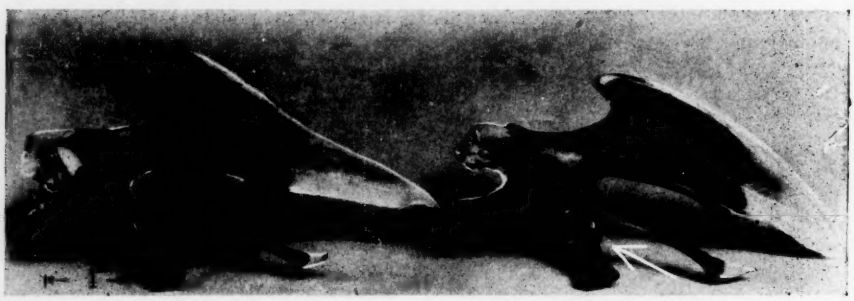
The United Nations is a sham—and nothing more, conceived in duplicity and doomed to futility. How the delegates at San Francisco managed to keep straight faces, Mr. Bromfield does not understand. These statesmen knew full well that the organization they were creating could never work in a practical world. Such an apparatus is alright for controlling illicit drug traffic and white-slavery, and as a clearing house for international weather reports. But a Family of Nations, never! Oddly enough, he looks for guidance to genial, wise, practical Joe Stalin. "Soviet Russia has developed . . . a new pattern of imperialism in its wholesale absorption of adjoining states . . . *into* the Union of Soviet Republics." "The long-run economic advantages to the individual citizen as well as to the whole nation are as evident as they are substantial." Geneticists who have shuddered at such grim repercussions of the Lysenko controversy as the disappearance of Vavilov will be pardoned their skepticism. Among these so-called advantages are the elimination of "countless frontiers" and "the endless feuds." This "half-formed, little-understood policy of political and economic *absorption*" is labelled "evolution," and is urged on us. Of course, he points out, this creeping amalgamation of small nations into large ones

is accomplished "at a cost of a certain amount of oppression and violence," and he concedes that it "would be economically, and perhaps socially" rather difficult. But if we carry on in good spirit and with a will, a benign hegemony will in time be achieved. Apparently the theory is that if the rapist smiles pleasantly and is well-mannered, the victim would be a fool not to enjoy herself. Nimbly overstepping such points of delicacy, the author sweeps us along to the penultimate millenium,— . . . "we should arrive then at a world divided completely between two great federations—one Russian-Asiatic-European, the other dominated by the great Anglo-Saxon nations . . ." What then? you ask. "Devastating wars would not be an impossibility," but on the whole Mr. Bromfield doubts it. Too devastating, too risky, too destructive. Maybe a few border clashes, an occasional skirmish perhaps. But finally, common sense and mutual need will show the way. And then will occur the Ultimate Amalgam, —" . . . the two great federations . . . will become united in a single world government—The United States of The World." (Not, you will note, "The World Union of Soviet Republics" or "The World Commonwealth of Nations." Virtue will out.)

I hereby nominate Louis Bromfield to be the First President of the USW, or the WUSR, or WCN, or whatever it is called, with the rank of Field Marshal.

MORTON STARK

September Error: Legend Mistakenly Describes Wrong Chicken Bone



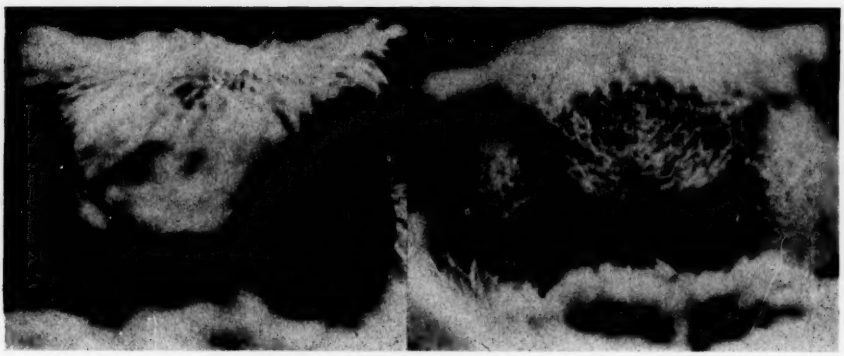
The cut here reproduced is Figure 10 of the September 1946 issue of the *Journal of Heredity*. It appeared originally on page 284 to illustrate a note entitled "An Unusual Growth of Bone in Chickens." The legend accompanying it erroneously described "an unusual growth" that does not correspond to the one described in the text. The variation was in the nature of a strut, suggesting a "functional adaptation," and this interesting feature was obscured by the erroneous legend.

In order to clear up the confusion the senior author, G. Davis Buckner, has placed an arrow pointing at the unusual growth of bone. In further amplification we quote from his letter: "Note the bony connection between the right lateral internal and external processes of the sternum in the specimen on the right as compared with the specimen on the left."

EGG AND EYE COLOR IN MUTANT SILKWORMS

Pigment Mutations of *Bombyx Mori* L. and Related Biochemical and Genetic Factors

MARIO TIRELLI*



SILKWORM EYES
Figure 12

The eyes of the silkworm moth are normally black. Mutant strains are known in which the eyes are lighter in color—pink, or even white, as in this instance.

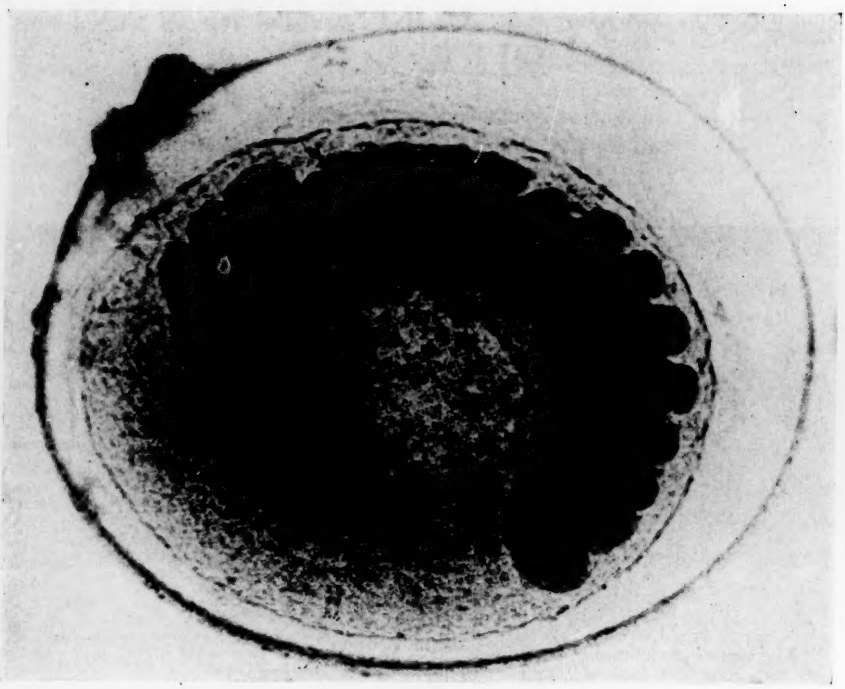
THE eye-color mutations in *Drosophila* stand high in importance for genetic research. Morgan's studies of this species, so fruitful for the development of the gene concept, began with the discovery of a mutant which differed by having white eyes instead of the normal red. Later an imposing series of other eye-color mutations was accumulated by Morgan and his collaborators—pink, ivory, eosine, cherry, to name only a few. These were important in the development of *Drosophila* genetics, and more recently have played an important part in furnishing the experimental material for such pioneer work as that of Beadle and Ephrussi[1] on the genetic control of eye-color pigments.

Kühn[8,9] and Kühn and Plagge[10] have also described red-eyed mutations in a normally black-eyed genus, the meal moth: *Ephestia kuhniella*. Their studies have also thrown new light on the interrelationship of genic, enzymatic and hormonal control of eye-color development.

The normal silkworm moth has black eyes (Figure 12) and its mature egg is grey. Selective breeding of an oriental race of silkworms with white cocoons produced varieties having three distinct eye colors: eosine, red, and dark red. A yellow mutant series having yellow, ivory, and white (albino) eyes was developed from another race of silkworms, one with yellow cocoons. We noted that among the normal gray eggs laid by these mutant races were some with red, pink, and albino serosas. There are numerous references in the literature† to the occasional laying of pink and particularly of albino eggs mixed together with the normal ones.

It is not the purpose of this paper to

*Stazione di Patologia Vegetale, Instituto Zoologia, Universita - Rome, Italy.
†Verson,[23] Toyama,[20] Grandori,[2] Iucci,[3] Tonon,[19] Kikkawa.[5]



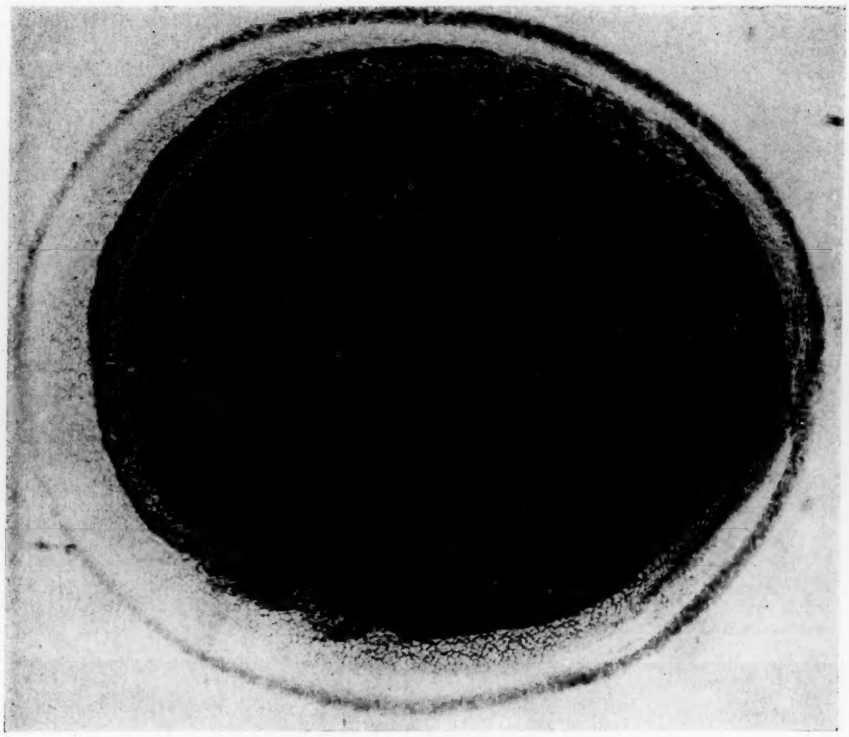
EMBRYO IN EGG
Figure 13

A white egg mounted in Canada balsam and viewed by transmitted light. The absence of pigment enables us to see clearly the outline, and even some of the interior structure, of the developing embryo

trace the rather complex interrelationship between egg color and eye color. That some relationship exists would seem, however, to be evident from the following tabulation of our observations:

Type No.	Eye color	Egg color
1	white or ivory	albino or light yellow
2	yellow	dark yellow
3	eosine	pink
4	red	red
5	dark red	bright red

It is pertinent to recall that the color of the eggs of silkworms, as of other insects, depends on three factors: yolk color, shell color, and the color of the serosa, a membrane consisting of flattened polygonal cells, located between the yolk and the shell. The yolk color generally is derived from the insect's food, the pigments passing from the haemolymph of the mother's body into the eggs. The yolk of silkworm eggs, for instance, is more or less yellow-colored, owing to the presence in the eggs of flavones and carotenoids, the pigments of the mulberry leaf. Serosa color, on the other hand, is produced by granules which are formed in the serosa cells themselves, by processes to be discussed in detail below. The shell pigment is generally derived as is that of the yolk, from the mother's haemolymph. In some instances, the shell is colorless;



OXYGEN INHIBITS PIGMENT FORMATION
Figure 14

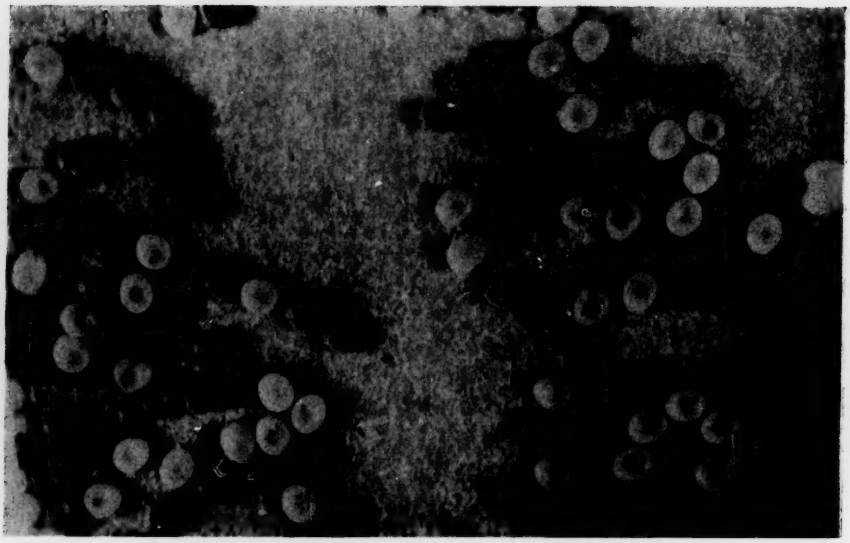
This egg was laid Sept. 15. It was put in boiled water three days later. On Nov. 12, it was removed from the water and mounted in Canada balsam. The embryonic stripe is well formed, but the pigment formation of the serosa cell has been inhibited, showing that pigmentogenesis is more quickly influenced by lack of oxygen than is the development of the embryo.

but even then, it can modify the general color of the egg by its structure or thickness. In normally pigmented eggs the embryo is not visible because of the dark brown pigment in the serosa (Figure 18). In white eggs, lacking dark pigment, the embryo instar is clearly visible through the transparent tissues (Figure 13).

In the mutants observed here, the serosas in each type had the same color as the mutant egg, so that apparently the egg color mutation concerns solely the serosa pigment, not that of the yolk or shell.

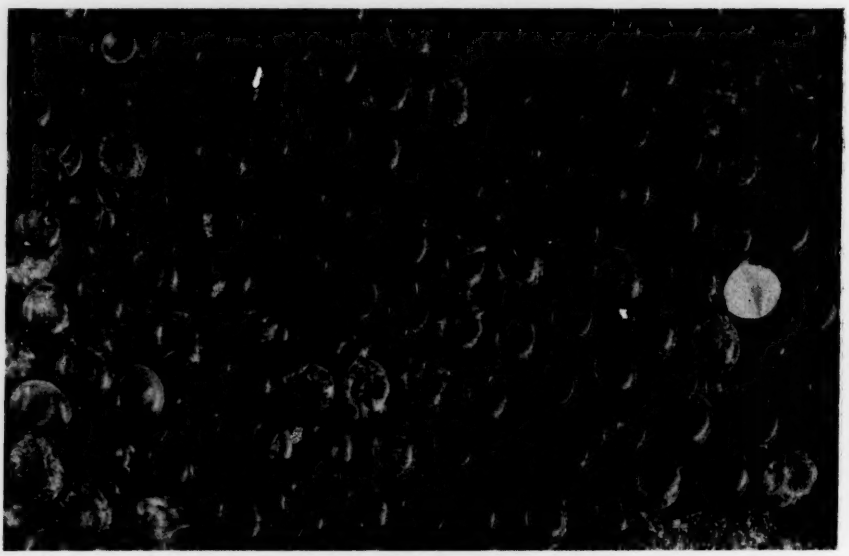
When newly laid, all silkworm eggs appear yellow, taking their color from the yolk and shell, since the serosa pigment has not yet developed. As the serosa develops, granules of melanic pigment* appear in its cells, yellowish at first, then turning pink, red, dark red, and eventually dark brown. This dark brown serosa pigment, as modified by the pigment of the translucent shell, is what gives the normal egg its charac-

*The distribution, behavior and size of these melanic granules in normal eggs has already been reported on by Tirelli.[14-18]



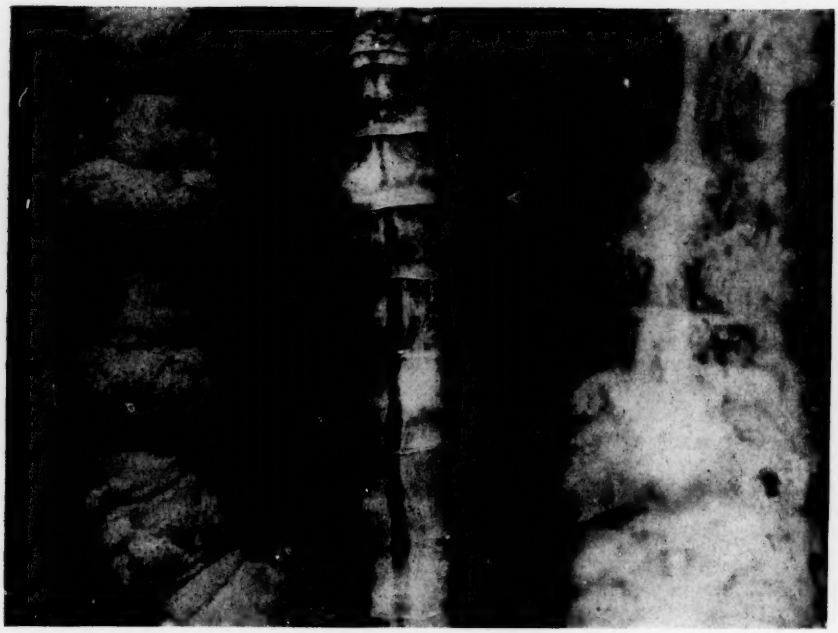
SEGREGATION OF EGG COLOR
Figure 15

Segregation in egg color in the eggs of an F_2 moth in a cross between albino egg and normal egg strains. In this plate the ratio of colored to white eggs is nearer 2:1 than 3:1, but the average of larger numbers yields a typical 3:1 ratio.



RED AND NORMAL SILKWORM EGGS
Figure 16

The normal eggs have a speckled appearance due to the somewhat irregular distribution of the pigment in the serosa cells. The red eggs show a more uniform coloration.



NORMAL AND MUTANT CATERPILLARS
Figure 17

A—A normal silkworm larva. *B* and *C*—larvae from a mutant race with white eyes, albino eggs and a transparent skin. In these some of the internal organs are clearly visible—notably the dorsal vessel (*B*) and some of the ventral ganglia (*C*.).

teristic gray color. In the mutants, apparently, something operates to arrest the pigment development in the serosa at different stages to produce the different colored mutant eggs.

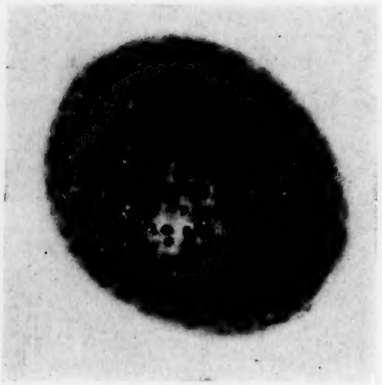
Pigmentogenesis in the Serosa

Experiments have shown that oxygen is necessary for pigment production. When eggs are stored in boiled water or varnished with paraffin oil, the process of pigmentogenesis is stopped. In eggs kept in boiled water, the embryonic processes advance almost to the embryonic stripe, but the formation of the pigment in serosa cells is inhibited (Figure 14).

The serosa cell pigmentation may therefore be considered as the result of an enzymatic process according to the following scheme: chromogen substance + enzyme + oxygen = serosa pigment.

As has been shown the serosa of normal fertilized eggs, shortly after they are laid, turns dark yellow, pink, then red and finally dark brown. In the mutant eggs, the formation of pigment stops at one of the intermediate phases, which therefore becomes the final phase as concerns that particular mutant race. This curtailment of pigmentogenesis is not due to lack of oxygen, nor to a deficiency of chromogen substance, since this substance is represented by the melanic granules which are present in all eggs, but which in the mutants remain pink or red instead of turning dark brown. The curtailment is therefore best explained as the result of an enzyme deficiency.

When the pigmentogenesis is complete, grains of dark pigment considered



SILKWORM EGG
Figure 18

The interior of the silkworm egg cannot be seen either by transmitted light or by mounting in Canada balsam because the serosa cells are filled with dark pigment. In the mutant strains with albinoid eggs the interior of the egg is visible because of the reduction or absence of pigment in the egg.

as melanin by some authors (*e.g.* Teodoro[13]) are formed in the serosa cells. It is known that the production of melanin passes through an intermediate stage of red pigment, or adrenochrome. It is likely that this red pigment is the one giving the normal red color to the eggs of various species of insects, as well as to the eggs of red-mutant silkworm races.

Matings With Mutants

Normal female moths, mated to albino-eyed males, laid eggs with dark serosas, only a little lighter than those of normal eggs. Albino females, crossed with normal males, laid eggs which remained much lighter than the normal eggs, their pigment being, however, dark, and not red or pink. This cannot be considered as due to an arresting of the pigmentogenetic process, at a more or less advanced stage, but represents a real case of pigment deficiency. In fact, normal eggs fertilized by albino sperm become almost as dark as the normally fertilized ones, while normal sperms, fertilizing albino eggs, produce a dark but quite incomplete pigmentation.

According to the findings of Kikkawa it is suggested that the chromogen precursor, kynurenine, is contained principally in the egg, and the enzyme is mainly transmitted by the sperm. Whatever the correct explanation may be, it is interesting to observe the immediate action of the normal sperm in modifying the biochemistry of the albino egg. In any case, all moths derived from albino eggs fertilized by normal sperms, or *vice-versa*, have black eyes, even if these moths derive from partially pigmented eggs, like those laid by albino females fertilized by normal males. These heterozygous moths, mated *inter se*, lay eggs in the proportions 75 per cent dark and 25 per cent albino, in a normal mendelian ratio (Figure 15).

Similar results are obtained by crossing normal and red-eyed moths (Figure 16). The cross-breeding between albino and red-eyed moths is less successful, owing, perhaps, to physiological incompatibilities, and many eggs remain unfertilized. In some successful cases, the F_2 showed a normal mendelian segregation.

It is believed that the physiogenetic mechanism determining the pigment production in the serosa of insect eggs is substantially the same in all species.

This point of view opens the way to further investigations. The appearance of such similar mutations, as those modifying egg-color in such different genera of insects, as the silkworm, *Drosophila* and *Ephestia*, recalls the hypothesis of homologous variations advanced by Vavilov.[22] Furthermore, these homologous mutations well agree with the fundamental physico-chemical determinism of the above described colors, which appear to be the same for all species of insects.

Other characters are correlated with the light-eye mutant series. First of all a slower rate of development; the character albino-eyes is also correlated with the transparence of the larval hypoderm, which makes it possible to see the internal organs of the developing larva (Figure 17).

A notable point that attracted our attention in connection with these mutant types is that similar mutations occur in the silkworm repeatedly, in different races and in widely separated countries. It is clear that a tendency to other genetic mutations exists in the silkworm. All these mutations can be classified as loss-mutations, in the sense that the normal pigmentogenetic process has been stopped. These changes appear to the author to be agents of the differentiation of the species, but their evolutionary significance remains to be proven.

Summary

Normally the silkworm has black eyes and grey eggs. The author observed a series of mutant races having red or yellow pigment in eyes and eggs. The biochemical basis of these differences is discussed, and these are related to the genetic behavior of these races when they are crossed. The evolutionary significance of the mutations is discussed.

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*I am indebted to Prof. W. C. Allee, who sent me the microfilms of these references.

◇

Huntington's Chorea

It is generally agreed that there is direct dominant transmission [of Huntington's Chorea] to the child from an affected parent of either sex.

Predictability is poorly understood beyond the facts: (a) that each child of a choreic parent has a one to one chance to develop the disease, (b) the ages of from 25 to 55 are those during which the disease is most likely to show itself. As he passes the age of 55, an individual from an afflicted family can have increasing assurance that he is not likely to develop the disease. If he does not develop it, he need not fear that his children will have it.

In 1872, Huntington wrote "Unstable and whimsical as the disease may be in other respects, in this it is firm, it never skips a generation to again manifest itself in another;

once having yielded its claims, it never regains them." This is essentially true today. However, a parent may die before the disease becomes manifest—but after he has transmitted the condition to his son. Most cases of "skipped generation" are of this type. Sporadic cases due to mutations or "sports" are believed to be rare but they can occur. Such cases may be transmitted to succeeding generations. The detection of a positive family history is often more difficult than many physicians apparently realize. There are many reasons why the history may be falsely negative:

(1) The patient may be an illegitimate offspring of a choreic parent. This is a fairly likely occurrence since Huntington's chorea is often characterized by immoral and lascivious behavior.

(2) The parent may die before the condition develops but after it has been transmitted to his children.

(3) For these or other reasons he may not know of his parent's condition.

(4) Patients and families, perhaps for shame, family pride, or other reasons, may deny the family history.

Possible Genetic Significance of Biotypes and Other Variations

While Huntington's chorea as a disease has many variations, these are not so marked among the individuals within a kinship. In other words, certain families have a unique trait or combination of traits which tend to reappear in all the choreics of that kinship. For example, one family may be characterized by an early age of onset, rapid progression, and marked severity of the symptoms. Another may be characterized by slow progression and mild personality disorders, or by the onset of the tremors in some special location as in the case of the family known as the "head nodders."

The occurrence and transmission of these various family differences enable us to recognize sub-varieties or biotypes.

* * *

The belief is widespread that choreic families also contain a large number of non-choreic members who are psychotic, emotionally unstable, epileptic, psychopathic, or otherwise defective. Although this is apparently true of many families, there are others in which there are a large number distinguished by economic, professional, or political attainments. Unfortunately, no good study on non-choreics in the affected families has been made which would settle this question. Even if a significantly high number of deviant non-choreic individuals can be shown to exist in these families, the psychogenic and social aspects of the genesis of their deviations must also be considered.

The psychogenic importance of the fear of chorea itself must be considerable in the case of non-choreic siblings. Likewise, psychologically traumatic situations are frequent in a family in which a parent is afflicted by this unfortunate disease.

Eugenic Considerations

The marriage rate and the fertility are both high. In one sample there were only 35 single as compared to 218 married choreics. The average choreic family probably has about five children.

The perversity of the human race in the face of such dangers is well known. Many cases are cited in which it has been impossible to dissuade normal people from marrying potential choreics, e.g.: one farmer, whose wife had died of the disorder, married her sister and she too developed the disease. In other words, even if predictability were possible, the problem would not be solved.

However, one of the first steps forward toward the control of this disorder should be an attempt to discover criteria which will indicate or at least give clues as to which members of a sibship will develop the disease. As far as is known to the author, no work has been done on this. The periodic examinatiton of every member of several sibships by modern methods may well provide the desired criteria. In addition to routine history, medical, neurological, and psychiatric examination, the studies should include electroencephalography and a battery of standardized tests. The latter might well consist of (a) a group of general personality tests like the Minnesota Multiphasic Personality Inventory and the Rorschach test: (b) psychometric tests of coordination, motor control, and steadiness; (c) tests for intelligence and for intellectual changes associated with brain damage.

It seems unlikely that effective treatment can be found though cortical extrapation, vitamin E and fever therapy are among the treatments being considered. Eugenic control may be possible at some future date through the combined efforts of several disciplines such as medicine, sociology, and genetics — B. C. SCHIELE, M.D., *The Journal-Lancet*, Nov. 1946. P. 394.

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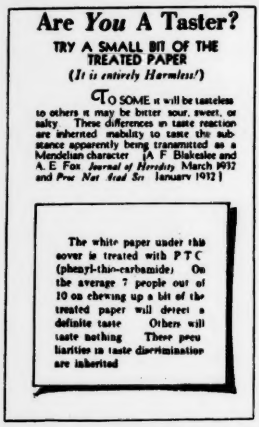
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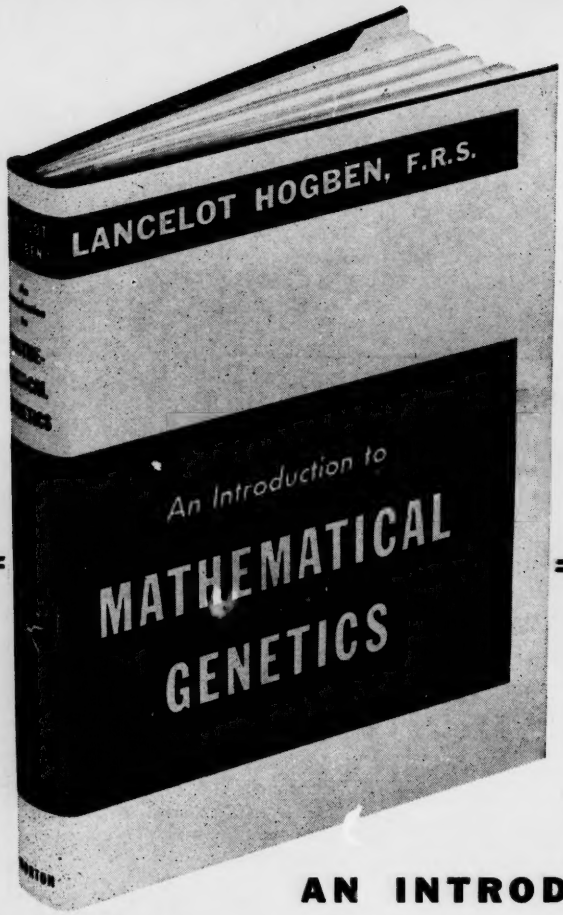

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